AN INVESTIGATION OF THE SOOTY MOULDS OF NEW SOUTH WALES. I.

Historical and Introductory Account.

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Introduction.

The term "Sooty Mould" is used to describe the dark brown or black felt of fungal mycelium often found on the leaves and branches of plants attacked by scale insects or aphis. The corresponding French and German terms are "Fumagine" and "Russtaupilze".

The fungi composing the mould are saprophytes which utilize the honey-dew secreted by scale insects and aphis. They therefore do no direct harm to the plant on which they occur, but may damage it indirectly by interfering with photosynthesis.

Sooty mould fungi are always strictly superficial and do not develop haustoria. The mould only adheres to the host leaf by virtue of the mucilaginous nature of the cell walls of the fungi composing it, and therefore flakes off readily when dry.

As well as being common on trees attacked by scale insects, sooty moulds have been recorded on the extrafloral nectaries of *Hibiscus* in Java by Boedijn (1931), and of cotton in India by Sawhney (1927).

It was originally thought that any particular sooty mould consisted of a single fungus in the same way that a particular kind of plant disease was due to a single pathogenic fungus. It is now known that in practically all cases sooty moulds consist of a number of fungi which live together forming a colony, and fruit concurrently. These different fungi have in common a dark-coloured mycelium, the cell walls of which have a tendency to become mucilaginous when wet.

The fungi which have been found to be of importance in the formation of sooty moulds can be classed into three groups: 1, Those which belong to the Capnodiaceae. 2, Those which belong to the Atichiaceae. 3, Those which belong to the Fungi Imperfecti.

To the Capnodiaceae belong the characteristic members of the sooty mould flora. In tropical countries where sooty moulds are particularly abundant it is not uncommon to find the perfect or imperfect fruits of as many as seven members of the Capnodiaceae in a single mould (Mendoza, in Stevens, 1925). It

is a striking fact that the most abundant and conspicuous fungi of sooty moulds should thus form a natural group systematically. They grow exclusively on the honey-dew of scale insects.

The members of the family Atichiaceae are aberrant saprophytic ascomycetes which grow on the leaves of trees, principally in the tropics. The most widespread species is *Atichia glomerulosa*, which is common in sooty moulds throughout Europe.

Those members of the Fungi Imperfecti which are found in sooty moulds are usually common saprophytic species such as *Cladosporium*, *Dematium* and *Penicillium* spp.

Sooty moulds are found throughout the world, but they differ widely in character in different localities. The maximum development is reached in wet forest areas, especially in tropical countries where rainfall is heavy and the atmosphere humid. Members of the Capnodiaceae and Atichiaceae are most numerous in the tropics. They are less important in cold temperate regions. Here the Fungi Imperfecti are plentiful and may be present in the sooty moulds to the exclusion of the Capnodiaceae and Atichiaceae.

A moist atmosphere is particularly favourable for the development of sooty moulds. Zopf (1879) and Thuemen (1890) noted their frequent appearance on the leaves of green-house plants. Thuemen recorded that in Europe their principal development takes place in the months July to November, especially in the late autumn, and stated that the amount of mould increased proportionately with the atmospheric humidity. Neger (1918) dealt in great detail with the necessity for a moist atmosphere for the development of sooty moulds. Mendoza (1932) pointed out that in the Philippine Islands where sooty moulds are very abundant, the greatest development takes place in the rainy seasons.

Historical Review.

A. *Systematic.*

Much confusion of nomenclature exists in the early descriptions and discussions of sooty mould forming fungi. This is due to several causes, the chief of which has already been noted. This was the tendency to regard any particular development of sooty mould as being formed of a single polymorphic fungus which produced a great variety of fructifications. A few workers only considered that each type of fructification found in a sooty mould was produced by a different fungus.

Another cause for confusion of nomenclature was the view, at first widely accepted, that the species of fungus causing a sooty mould differed with the host plant, as with parasitic fungi. Consequently identical fungi were often given different names if they were found on different host plants.

In many cases, too, descriptions of type species and genera were inadequate, and consequently were variously interpreted by later workers. The result was that a very heterogeneous group of fungi was in many cases attributed to the one genus.

A brief summary is given below of some of the most important changes in nomenclature of the more widespread and better known mould-forming species of fungi.

(i) Capnodiaceae.

Amongst the earliest sooty mould genera to be described were *Antennaria* Link in 1809, *Apiosporium* Kunze in 1817, *Fumago* Pers. in 1822, and *Scorias* Fries in

1825. During the following few decades many species were ascribed to these genera, most of them on inadequate grounds.

Amongst the most important of the species described were *Fumago citri* Turp., the "citrus mould", and *Fumago salicina* Pers., the "willow mould", and *Fumago vagans* Pers., which was stated to be widespread.

In 1849 Montagne described the genus *Capnodium* to include *Fumago salicina* and *F. citri* on the ground that the type species of *Fumago* was based on an imperfect fructification. *Capnodium* was described as having club-shaped perithecia, and 4-septate, yellowish-brown ascospores.

Tulasne (1863) retained the older nomenclature. In describing *Fumago salicina* Pers., he united under this name some 14 fungi which had been described as different species. Some of the species included by him were *Fumago vagans* (in part) and other species of *Fumago*, *Cladosporium* spp. and *Fumago citri* (i.e., *Capnodium citri* of Montagne). He also considered that *Antennaria elaiophila* Mont. (which is the same as *Torula oleae* Castaigne) and *Antennaria semi-ovata* B. & Br. are probably identical with *Fumago salicina*.

Tulasne placed the Fumagines in the Sphaeriei.

Farlow (1876) described the sooty mould of oranges in California as belonging to the species *Capnodium citri* Mont. He expressed the opinion that *Capnodium citri* and the fungi described as *Fumago citri* Pers., *Antennaria elaiophila* Mont. and *Fumago salicina* were all identical, thus confusing two very distinctive fungi, *Capnodium citri* and *C. salicinum*.

Zopf (1878) described in detail the development in culture solutions of a sooty mould fungus common at that time in the glass houses in Berlin, growing saprophytically on the secretions of aphis and scale insects. This fungus he classified as *Fumago*, but since he found no perfect fruit and none developed in his cultures, he was unable to assign it to any definite species. Zopf found that this species was extremely polymorphic. In pure culture it produced a large number of different kinds of fruiting structures showing all gradations from free conidiophores to closed pycnidia. This work appeared to confirm the general opinion that all sooty moulds are polymorphic.

Penzig (1882) described the sooty moulds of citrus, which had been studied intensively because of the economic importance of the host plants, as belonging to the genus *Meliola*, as *Meliola citri*. This classification was also used by Saccardo who considered that there were three species of *Meliola* which formed sooty moulds on citrus, *Meliola citri*, *M. camelliae* and *M. Penzigi*. Penzig considered that the two latter were probably identical.

Gaillard (1892), in a monograph of the genus *Meliola*, excluded from this genus the fungi responsible for the sooty moulds of citrus.

Weber (1896) retained the older classification of Saccardo, referring the sooty moulds of citrus in Florida to the species *Meliola camelliae*.

Lindau, in "Die Naturlichen Pflanzenfamilien" (1897), made further changes in nomenclature. He included the species previously known as *Capnodium* and *Fumago* in the genus *Apiosporium* Kunze, except for five species of *Fumago* retained in the Fungi Imperfecti near *Alternaria*. The genus *Antennaria* Link was retained and in it was included *Limacinia*, a genus described by Neger in 1896, as forming a sooty mould on the leaves of trees in Juan Fernandez. *Apiosporium*, *Antennaria* and the sooty mould *Scorias spongiosa* were included by Lindau in the Perisporiaceae with *Meliola* and *Perisporium*.

Another change in nomenclature was later made by Saccardo, who placed the sooty moulds of citrus in the genus *Limacinia* Neger, since the perithecia produced by them were sessile. He limited *Capnodium* to those species with stalked or vertically extended cylindrical or club-shaped perithecia, of which the type is *C. salicinum* (see von Hoehnel, 1909*b*, and Arnaud, 1911). In contrast to Lindau, Saccardo considered that *Antennaria* is the unripe fruit of *Capnodium*, and that *Capnodium* is not identical with *Apiosporium*. He placed the sooty mould genera, including *Limacinia*, *Scorias*, *Capnodium*, etc., in the Capnodeii, a section of the Perisporiaceae.

Lindau's scheme of classification was used by Sorauer (1908) in his handbook of plant diseases, and is retained in the later editions.

Clements (1909) largely followed the arrangement of Saccardo, but placed *Limacinia* as a synonym of *Meliola*, evidently ignoring its saprophytic nature.

Von Hoehnel (1909*a*) pointed out that the genus *Apiosporium* Kunze was invalid, since the type specimen is a sclerotium. He reviewed the genus in detail and reclassified the species referred to it into a number of other genera. He also reviewed the genus *Antennaria* at some length. The description of the type species of *Antennaria*, *A. ericophila* Link, is said by von Hoehnel (1909*b*) to be inadequate. According to him most of the species subsequently placed in this genus were incompletely known fungi of doubtful position. The type species was redescribed by Neger, and Neger's fungus has been shown by von Hoehnel to be the imperfect stage of *Coleroa Straussii* (Sacc. & R.) v. H., a parasitic species of the Sphaeriales. According to von Hoehnel, therefore, *Antennaria* Link becomes *Coleroa* Rab. In any case the generic name *Antennaria* is invalid, since it had been applied previously to a genus of the Compositae by Gaertner, and was superceded by the name *Antennularia* of Reichenbach in 1828 (see von Hoehnel, 1909*a*).

Since then the name *Antennularia* has been used by von Hoehnel to designate the pear-shaped pycnidia of *Coleroa* and the sooty mould genus *Limacinula* (1909*b*). It has been used by Woronichin (1926) and Boedijn (1931) for the pycnidial fruits of various members of the Capnodiaceae.

In describing a new sooty mould, *Limacinula samoensis*, von Hoehnel (1909*b*) reviewed the genera and species of the Capnodeii as described by Saccardo. He considered that the sooty mould fungi which constitute this section form a very natural group. He maintained, however, that the genus *Limacinula* should not be placed in the Capnodeii, and suggested the formation of a new family, the Naetrocymbeii, to include it, this family to be placed in the Sphaeriales. The Naetrocymbeii were said to parallel the Capnodeii in having similar mycelium and conidia, but to differ in the formation of the perithecium which is never cartilaginous and tough as in the Capnodeii, but is soft and membranous with a well developed ostiole. There were two genera in this new family: *Naetrocymbe* Korb. and *Limacinula* Sacc., the type being *Limacinula javanica* (Zimm.) Sacc.

In 1910 von Hoehnel raised the subsection of Saccardo to the position of a family, the Capnodiaceae, and gave a scheme of classification.

A very different attitude was adopted by Arnaud (1910*a*, 1910*b*, 1911, 1912). He did not consider that the genera placed by von Hoehnel in the Capnodiaceae formed a natural group, but maintained that they are members of the Sphaeriaceae. The individual species of sooty moulds he re-classified into already known genera of the Sphaeriaceae, *Pleosphaeria* and *Teichospora*. *Limacinula*, *Capnodium* and *Teichosporina* were taken as subsections of the genus *Teichospora*. The genera *Limacinia* and *Scorias* were retained and transferred to the Sphaeriaceae.

Arnaud reviewed in considerable detail the sooty moulds described from citrus plants, and dealt very adequately with the confusion of nomenclature existing in this group. He gave a full list of synonyms. The result of his review was that he placed the fungi previously referred to as *Limacinia Penzigi*, *L. citri* and *L. camelliae* by Saccardo (i.e., *Fumago citri* Turp., *Capnodium citri* Mont., and *Meliola citri*, *M. camelliae* and *M. Penzigi* Sacc.) in the genus *Pleosphaeria*. He considered that all are identical and renamed the species *Pleosphaeria citri* Arn. Some of the imperfect fruit attributed by older authorities to this fungus were considered by Arnaud to belong to a newly described sooty mould *Teichospora meridionale* Arn.

Arnaud's scheme of classification was not accepted by contemporary German mycologists, and in 1916 Theissen put forward a new classification, retaining the family Capnodiaceae as a division of the Perisporiales. He also expressed doubts as to the validity of the family Naetrocymbeii as described by von Hoehnel (1909*b*).

A much more comprehensive scheme of classification was given by Theissen and Sydow (1917). Here again the family Capnodiaceae is retained. The primary divisions of the family were based on the character of the perithecium, whether stalked or sessile, and on the colour and septation of the ascospores. In this scheme the genera in the Naetrocymbeii (now known to be identical with the Coccodineii) were placed in the Capnodiaceae. Here also were placed the genera previously classified as Chaetothyriaceae, a subsection of the Microthyriaceae, by Theissen (1913), and a fungus named by von Hoehnel *Treubiomyces*, which had originally been placed in the Nectreii. According to Theissen and Sydow the Capnodiaceae included 23 genera.

The classification of Theissen and Sydow was followed by Mendoza (Stevens, 1925) in his treatment of the sooty moulds from Hawaii.

A rather different scheme was outlined by Spegazzini (1918) in his review of the family. The synonyms accepted by him are not always in agreement with those advocated by Theissen and Sydow. He made the primary divisions of the family on the character of the perithecium as did Theissen and Sydow. Twenty genera were included in this scheme. Spegazzini considered the imperfect fruits of the Capnodiaceae separately under different generic and specific names as the Capnodeii Imperfecti.

Von Hoehnel (1918) again maintained that the division of the Capnodiaceae into two families, the Capnodiaceae proper and the Coccodineae, was justified.

Von Hoehnel's opinion was accepted by Woronichin (1925), who proposed that the sooty mould family should be elevated to the rank of a class equal to the Sphaeriales and the Perisporiales. For this he proposed the name Capnodiales, and attributed to it three families: i. The Antennulariellaceae, Woron.; ii. The Coccodineae, v. H.; iii. The Capnodiaceae, v. H. The family Antennulariellaceae included one genus *Antennulariella* Woronichin, which was described as having perithecia of the typical perisporiaceous type, in the sense of Theissen and Sydow (1917), and the imperfect fructifications and mycelium of the Capnodiaceae. Woronichin considered that the Chaetothyriaceae of Theissen (1913) should be classed as an offshoot of the Capnodiales, which approach the Microthyriaceae in the method of formation of the perithecia.

The new class Capnodiales was not accepted in the classification of Clements and Shear (1931), and the type genus *Antennulariella* of the family Antennulariellaceae was placed by them amongst the doubtful fungi.

The raising of the Capnodiaceae to the position of a class seems unjustified at present, and investigations of the life histories of the sooty mould fungi are necessary before even the relationships of the fungi now classed together in the Capnodiaceae can be adequately assessed.

Woronichin (1926) proposed a different classification for the fungus *Pleosphaeria citri* Arn. He did not agree with Arnaud that this fungus belongs to the genus *Pleosphaeria*. He examined material from the herbarium of Jaczewski, which had been identified by Briosi and Cavara, and which he maintained was identical with that described by Arnaud. He described the perithecium as being like a truncated cone in side view and spherical when viewed from above. The wall is of dark brown cells and not truly parenchymatous, the ostiole is formed by the gelatinization of the cells at the apex of the perithecium, and it is fringed by a number of pointed bristles. Woronichin stressed the fact that hyphal threads can be traced from the perithecium wall into the surrounding mycelium. The spores are pale yellowish-green and 3–4 septate. His opinion was that the fungus undoubtedly belongs to the genus *Aithaloderma* which is placed by him in the Chaetothyriaceae, but which is placed in the Capnodiaceae by Theissen and Sydow. Woronichin proposed the new combination *Aithaloderma citri* Woron. for the fungus, and considered that it is closely related to *A. colchicum* Woron.

Gaumann (1928) accepted the classification of the sooty moulds proposed by Arnaud. He placed them in the new family Amphisphaeriaceae of the Sphaeriales, because of the presence of an ostiole in the perithecium of most of the members.

The classification of the sooty moulds adopted by Clements and Shear (1931) was a modification of that of Saccardo. It was based primarily on the colour and segmentation of the ascospores. The number of genera recognized was 34. Most of these are superficial in habit, but several have a subcuticular mycelium.

As has been pointed out by many writers on the subject (see Clements and Shear, 1931), the fungi classed in the Capnodiaceae show relationships both with the Sphaeriales and with the Perisporiaceae, and in many respects appear to be intermediate between them.

Caldariomyces Fumago Woron.—The fungus described by Zopf (1878) as *Fumago* has been the cause of some differences of opinion. Zopf himself gave it no specific name. Zopf grew this fungus in pure culture in solutions of various concentrations of sugar and followed the development of a great variety of fructifications. The simplest of these are the "Konidienbuscheln", bundles of conidiophores which cut off conidia at their apices. By overgrowth of the marginal hyphae of such fructifications as these, all gradations are produced between this type and stalked pycnidia with long or short necks according to the degree of overgrowth. Gradations between these and short-stalked pycnidia with long or short necks are also found. "Gewebefruchte", which Zopf considered to be truly parenchymatous in origin as compared with the previously described pseudo-parenchymatous fruits, were also described. These are small pear-shaped pycnidia. Zopf also found that, after some months of cultivation, yeast-like conidia were produced by his fungus, and these under certain conditions reproduced themselves by budding after the manner of yeasts. Other conidia were also described.

Lindau, Arnaud, Gaumann and others have attributed the various fructifications described by Zopf to the fungus *Capnodium salicinum* Mont. Neger (1918) has advanced evidence to show that this is not the case. In Germany,

according to Neger, the fungus described by Zopf is found only in glass houses, whereas *Capnodium salicinum* is very widespread. Zopf's fungus and *Capnodium salicinum* were shown by Neger to be quite distinct. Since, therefore, the perfect stage of the glasshouse fungus is unknown, Neger referred to it as *Fumago vagans* Pers. Woronichin (1926), however, maintained that it could not belong to the genus *Fumago* as described by Persoon, and proposed for it a new name, *Caldariomyces Fumago* Woron. He considered that the fungus should be placed in the Fungi Imperfecti, near *Graphium*. According to Woronichin *Fumago vagans*, as generally known, is a mixture of *Dematium pullulans* and *Cladosporium herbarum*. Clements and Shear (1931) did not accept Woronichin's classification and referred to the genus *Caldariomyces* as a synonym of *Fumago*. According to their key, however, the fungus described by Zopf cannot be placed in the genus *Fumago* which is near *Alternaria*.

(ii) Atichiaceae.

A fungus, *Atichia glomerulosa*, which is very frequently met with in European sooty moulds (see Neger, 1918), has been the subject of much debate. Brief reviews of the genus have been given by von Hoehnel (1910), Cotton (1914), and Neger (1918).

The fungus forms small round or lobed cushion-like colonies 0·5 to several millimetres in diameter on the leaves of trees. These appear black macroscopically and consist of radiating threads of yeast-like cells embedded in mucilage. The inner cells are hyaline, the outer ones are darker and have thicker walls. The cells contain numerous droplets of oil. The colonies are small and dark when dry, but because of their mucilaginous nature they absorb water readily, and swell at once to several times their original size.

Reproduction takes place by the formation of ascospores in asci which arise near the surface of the colony. They may be grouped in special cushion-like areas, or scattered throughout the thallus. Asexual reproduction takes place by the production of many-celled conidia called "propagulae" which are produced in great numbers in concavities in the thallus. They consist of small branch systems of cells similar in appearance to those composing the remainder of the thallus, the shape varying with the species. Pycnidia of typical form have also been described.

The genus *Atichia* was described in 1850 by Flotow for the fungus known as *Collema glomerulosa* Ach., which was previously placed in the Collemaceae (Lichens). Lindau (1897) placed the fungus in the Bulgariaceae as a doubtful genus.

A fungus of the same genus was described by Patouillard in 1904 under the name *Seuratia*. Patouillard at first considered it to be a new genus of the Capnodiaceae. Later Vuillemin (1905) in describing *S. pinicola* (which has been shown by von Hoehnel to be identical with *Atichia glomerulosa*) made a new family, the Seuratiaceae, for these fungi, and pointed out that they showed affinities with the Capnodiaceae and the Celidiae. This classification was accepted by Patouillard (1906).

Von Hoehnel (1910) pointed out that the genus *Seuratia* was identical with the previously described *Atichia*, and placed it with the Saccharomycetes. He placed in the genus *Atichia* the fungus known as *Heterobotrys* Sacc., frequently found associated with sooty moulds, and described by many writers as a spore form of members of the Capnodiaceae. The type species *Heterobotrys paradoxa* is now regarded as being identical with *Atichia glomerulosa* (Cotton, 1914).

Mangin and Patouillard (1912), in describing a fungus belonging to the genus *Phycopsis* which is closely related to *Atichia*, maintained that *Phycopsis* and *Atichia* cannot properly be classed in either the Capnodiaceae or the Saccharomycetes, and suggested a new group, the Atichiales, with one family, the Atichiaceae, and two genera, *Atichia* Flot. and *Phycopsis* Man. and Pat. They placed this group at the base of the Ascomycetes, parallel to the filamentous Ascomycetes. They pointed out that the fungi placed in the Atichiales resemble the Saccharomycetes in the habit of budding, and the Myrangiales in the method of reproduction. They considered that the group was derived from the Florideae, and compared the propagulae with the soredia of the lichens.

Gaumann (1928) retained the family Atichiaceae, describing the fungi belonging thereto as of doubtful affinities. He considered that they may be related to the yeasts or may be reduced Discomycetes.

Clements and Shear (1931) placed the genera of the Atichiaceae in a new class, the Argyriales, in the family Argyriaceae. The members of this new class are described as being characterized by extreme reduction of the apothecium. They are said to have affinities with the Bulgariaceae, Ascobolaceae, Pezizaceae and Myrangiaceae and are probably derived from these families by reduction. The Argyriales is, therefore, not a natural class and contains a very heterogeneous collection of fungi.

(iii) Fungi Imperfecti.

In 1888, Laurent carried out a number of cultural experiments on sooty moulds. He made a great number of isolations on nutrient gelatine plates of fungi from sooty moulds from various parts of Europe and tropical countries. The fungi he recorded as occurring most commonly were, in order of abundance, *Cladosporium herbarum*, *Penicillium cladosporioides* (now considered to be the same as *Cladosporium herbarum*), and *Dematium pullulans*. Yeasts were also obtained. He grew these fungi in pure culture, and studied their reactions to heat and cold. He found that in all cases a dark mycelium was ultimately formed by each fungus (dark coloured spores in the case of the yeasts). This dark mycelium was very similar to that forming the sooty moulds on leaves. As a result of this and of other experiments in which he found that conidial fructifications resembling each other were occasionally developed by the three fungi, he came to the conclusion that these three species of fungi were forms of the one fungus, *Cladosporium herbarum*. He explained this variability as being induced by the action of the sun. The fungus *Capnodium salicinum* was regarded as being the perfect stage of this supposedly very polymorphic fungus.

Dematium pullulans was first described by de Bary (1887) as an epiphyte on the leaves of trees. In culture it produces thin-walled conidia laterally in great abundance; these may grow by budding after the manner of yeasts. Under adverse conditions thick-walled chlamydospores and conidia are formed. It is a saprophyte common in all parts of the world.

Schostakowitsch (1895) carried out extensive cultural experiments on sooty moulds, examining them particularly with regard to the conidial fructifications. He found three species of the Fungi Imperfecti to be associated with the formation of sooty moulds, *Cladosporium herbarum*, *Dematium pullulans*, and *Hormodendron* sp. He found no justification for Laurent's conclusion that *Cladosporium* and *Dematium* are expressions of the one fungus, and considered that these species

and *Hormodendron* are culturally quite distinct. Zopf's results showing the extreme polymorphism of *Fumago* were confirmed, but Schostakowitsch believed that the yeast-like conidia ascribed by Zopf to *Fumago* were in reality a yeast contaminant and not part of the life cycle.

Berlese (1895) and Planchon (1902) supported Schostakowitsch's criticism of the results obtained by Laurent. As the result of extensive experimental work they found no cultural evidence of relationship between *Cladosporium* and *Dematium*.

Arnaud (1910*a*) mentioned that *Cladosporium* and *Dematium* are the most important members of the Fungi Imperfecti which go to the formation of sooty moulds in France. He also sometimes found spores of other common saprophytic members of the Fungi Imperfecti in sooty moulds.

In 1917 Neger published the results of his important cultural work on the sooty moulds. He found that there are a great many more fungi composing these moulds than was generally accepted. *Dematium pullulans*, *Cladosporium herbarum*, *Coniothecium* sp., *Triposporium* sp., *Atichia glomerulosa*, *Hormiscium pinophilum* were frequently found, the first two being the most important. *Helminthosporium* sp., *Penicillium* spp., *Botrytis cinerea*, yeast and bacteria were also occasionally obtained, together with the sterile mycelium of *Bulgaria polymorpha*, *Herpotricha nigra*, *Xylaria hypoxylon* and others. He insisted that it is necessary to make cultural as well as microscopical examinations of sooty moulds in order to ascertain their composition.

Dematium pullulans has been regarded by some mycologists, notably Brefeld (see Hoggan, 1923), as being a collective name for the imperfect form of a number of the Sphaeriales. Amongst the species to which it has been referred are *Sphaerulina intermixta* and *Plowrightia ribesia*. Hoggan (1923) gave a detailed review of literature concerning *Dematium*, and showed that it has no connection with the fungus *Plowrightia*. Bennett (1928*b*) later obtained the perfect stage of *Dematium* and showed that it is unlike any of the Capnodiaceae or Sphaeriales.

Bennett (1928*a*) gave a summary of evidence to support the contention that *Cladosporium herbarum* and *Hormodendron* are not distinct species. Schostakowitsch distinguished them by their heliotropic reactions, the nature of the conidial wall and the type of growth in certain concentrations of potassium nitrate, but recent workers have found no evidence for their separation.

B. *Physiological.*

In the earliest studies of sooty moulds there appears to have been some doubt as to whether the fungi were saprophytes or parasites. Tulasne, for example, did not believe that these fungi were associated with scale insects, and pointed out that they may occur on trees which are unaffected by scale. As later writers have shown, however, if this is the case, it is always found that neighbouring trees are affected and that the honey-dew has dropped from them.

Although Zopf (1878) grew *Fumago* in culture media of various sugar concentrations, his chief aim was to obtain stages in the life history and not to examine the physiological requirements of the fungus. More definite is the work of Laurent (1888) on *Cladosporium* and *Dematium*. He studied the effect of light and temperature on these fungi and confirmed de Bary's record that *Dematium* can remain alive for long periods of drought in the form of chlamydospores. Schostakowitsch (1895) greatly extended the work of both

Zopf and Laurent. He studied conidium formation by *Fumago* and *Dematium* at various temperatures and on various media. He found that *Dematium* showed great variability. At laboratory temperatures and in media of fairly low sugar concentration, thin-walled conidia, which grow by budding after the manner of yeasts, are cut off. But the production of these conidia decreases with increase in concentration of sugar in the medium, until it ceases at about 50% sugar. After prolonged culturing at 30° C., *Dematium* degenerates into a yeast and reproduces entirely as such until conditions of lower temperature are restored.

The work of Hoggan (1923) showed that *Dematium pullulans* is very variable in culture, and that the thick-walled chlamydospores sometimes formed by it have remarkable powers of resistance to desiccation over long periods.

The Sooty Moulds of New South Wales.

In the Sydney district the late spring and summer months are usually fairly dry, so that during the hottest part of the year conditions do not appear to be favourable for the growth of sooty moulds. Sooty moulds are common, however, at all times of the year, and show a definite increase in quantity during the winter. Sooty moulds are found on a great variety of plants affected by scale insects, aphis, etc. In spite of the frequency of the mould, the total number of members of the family Capnodiaceae so far known from New South Wales is not large. It therefore seemed that it might prove of interest to investigate some of the moulds culturally in order to ascertain whether members of the Fungi Imperfecti and the Atichiaceae are present to the same extent as described by Neger in the sooty moulds of Germany.

A. *Fungi Present in the Sooty Moulds of New South Wales.*

(i) The Capnodiaceae.

Fifteen species of the Capnodiaceae are recorded from Eastern Australia by Cooke (1892), McAlpine (1895) and in the index of Australian fungi compiled by Brittlebank, which is in the possession of the Council for Scientific and Industrial Research at Canberra. These are listed below, together with synonyms and notes on the present systematic position of the fungus.

Fungi recorded by Cooke are indicated by (C), additional species recorded by McAlpine by (M), and further additions recorded in Brittlebank's host index by (B).

1. *Capnodium citri* B. & Desm. Victoria and Queensland (C).—*Synonyms*: *Capnodium citri* Mont., *Apiosporium citri* Br. & Pass. (see Lindau, etc.), *Meliola citri* Sacc., *Limacinia citri* Sacc., *Pleosphaeria citri* Arnaud, *Aithaloderma citri* Woronichin. This fungus does not belong to the genus *Capnodium* as now accepted, and it is probably best placed in the genus *Aithaloderma*.

2. *Capnodium elongatum* B. & Desm. Queensland (C).—*Synonyms*: *Polychaetella elongata* Spegazzini, *Capnodium Persoonii* B. & Desm. (Woronichin, 1926). Arnaud considered that this species is a doubtful one.

3. *Capnodium australe* Mont. Queensland (C).

4. *Capnodium salicinum* Mont. Eastern Australia (C).—*Synonyms*: *Fumago salicina* Pers., *Apiosporium salicinum* (see Lindau, etc.), *Teichospora salicina* Gaumann (see Arnaud, 1910*a*, 1911). This is a very widely distributed fungus, being common in the sooty moulds of all parts of the world.

5. *Capnodium Walteri* Sacc. Victoria (M).

6. *Capnodium araucariae* Thuem. Victoria (B).—*Synonym*: *Polychaetella araucariae* Spegazzini. The type species was described as an imperfect fruit, probably of *Capnodium australe*.

7. *Capnodium armeniaccae* Thuem. Victoria (B).—This is considered to be a doubtful species by Arnaud.

8. *Capnodium callitris* McAlp. New South Wales (B).—*Synonyms*: *Limacinia callitris* Sacc., *Limacinula callitris* Spegazzini, *Phraymocapnias callitris* Theissen and Sydow. The nomenclature of Theissen and Sydow is accepted.

9. *Capnodium casuarinae* McAlp. New South Wales (B).—*Synonym*: *Microxyphium casuarinae* Spegazzini. The description of the type was based on an imperfect fruit form.

10. *Capnodium citricolum* McAlp. Eastern Australia (B).—*Synonyms*: *Teichospora citricola* Arnaud, *Limacinula citricola* Spegazzini.

11. *Capnodium nerii* Rab. Victoria (B).—Arnaud gave this species as the pycnidial form of *Capnodium* (*Teichospora*) *meridionale* Arnaud.

12. *Antennaria scoriadea* Berk. New South Wales (C).—*Synonyms*: *Antennularia scoriadea* (Berk.) Reich., *Capnodium scoriadeum* von Hoehnel. The fungus found in New South Wales is best known provisionally as *Antennularia scoriadea*.

13. *Antennaria semi-ovata* B. & Br. Queensland (C).

14. *Antennaria Robinsoni* B. & Br. Victoria (C).—This and the preceding species have been described in the imperfect condition only.

15. *Zukalia loganiensis* Sacc. & Berl. Queensland (C).—This species is now known as *Chaetothyrium loganiense* Theissen.

The most important species of the Capnodiaceae which occur in New South Wales are *Capnodium salicinum* Mont. and *Antennularia scoriadea* (Berk.) Reich.

Capnodium salicinum.

This fungus is common throughout the year, especially after the autumn rains. It appears to be widespread throughout the State and is found on a great variety of plants. The pycnidial fructifications vary considerably in size. They are usually stout and columnar, tapering towards the mouth. The mouth is fringed by a few stiff hyaline hair-like hyphae. Occasionally cases of branching pycnidia are found; in some cases young pycnidia may develop from the walls of old ones.

The pycnidiospores of *Capnodium salicinum* vary considerably, their appearance depending on their age at the time of ejection from the pycnidium, this in turn depending on the weather. The spores are only ejected in damp or wet weather. The interior of the pycnidium contains mucilage, probably secreted from the cells of the wall. In damp weather this takes up moisture and swells, bulging out through the ostiole and taking with it any detachable spores. Outside the pycnidium more moisture is taken up, so that the spores appear suspended in a clear liquid drop at the mouth of the pycnidium. If this ejection takes place when the spores are first cut off, they are oval, hyaline, single-celled, and measure $6–8\mu \times 4–5\mu$. But if ejection is delayed the spores may have developed further and have become dark brown. In this condition they may be two-celled and $10–12\mu \times 6–8\mu$, or four-celled and $15–18\mu \times 6–8\mu$. Most of the spores are at the same stage of development in the pycnidia of any one colony.

The pycnidia are produced first by the mycelium and are best developed at about the time of the first appearance of the young perithecia. After this their activity declines and they ultimately cease spore production, and vegetative

hyphae grow out from their sides, giving them a hairy appearance. They probably fruit for several weeks continuously.

The perithecia measure 100–150μ × 90–120μ; the ascospores are brown, 15–19μ × 7–9μ, usually three-septate laterally, with additional longitudinal septa giving them a muriform appearance. They may be slightly constricted at the median septum.

ANTENNULARIA SCORIADEA.

Von Hoehnel (1909*c*) has reviewed the species *Antennularia scoriadea* (Berk.) Reich. in some detail. The type specimen from New Zealand is badly preserved, but he examined other similar specimens from New Zealand, describing the perithecia and renaming the species *Capnodium scoriadeum* (Berk.) v. H. The pycnidial form of a species very similar to this is very common around Sydney, but, until the perithecial fruits have been found, it is advisable that the New South Wales fungus should be known as *Antennularia scoriadea*.

As a rule sooty mould colonies in which this fungus is predominant are very thick and spongy in appearance. The mycelium is dark brown and torulose. The pycnidia are pear-shaped, 40–50μ × 60–70μ, and produce small hyaline spores about 2μ in diameter. *Antennularia* occurs very frequently as a minor constituent in moulds in which other fungi are dominant. In some such cases it may not be found in the fruiting condition, and its presence is only revealed by platings.

Besides *Antennularia scoriadea* and *Capnodium salicinum* there are other members of the Capnodiaceae present in the sooty moulds of New South Wales, which produce various forms of pycnidia, but have not yet been found associated with perithecia. These will be discussed at greater length in a later communication. Several species of *Capnodium* may occur in the one mould.

(ii) Atichiaceae.

A common constituent of the sooty mould flora is *Atichia glomerulosa*. Not only is it found growing with sooty moulds, but it is also common alone on the leaves of rain forest trees, and the individual colonies may attain considerable size. From his descriptions and figures, as well as the fact that he called this type of structure *Heterobotrys*, it is very probable that the glomerulae described by McAlpine as the conidial fructifications of *Capnodium citricolum* and *C. callitris* are colonies of a species of *Atichia*.

(iii) Fungi Imperfecti.

A number of types of conidia belonging to genera of the Fungi Imperfecti have been recognized in microscope examinations of New South Wales sooty moulds. The most frequent of these are *Cladosporium*, *Alternaria* and *Triposporium*.

In order to investigate fully the Fungi Imperfecti present in moulds cultural experiments have been carried out.

Methods.—Platings were made in the following manner. Portions of a sooty mould of about 4 sq. mm. (less in the case of a thick mould) were scraped off the affected leaf with a sterile needle and thoroughly ground up in a drop of sterile water on a glass slide. A drop of the suspension of broken fragments of mycelium and spores was transferred to a sterile Petri dish. This was then poured with a thin layer of potato dextrose agar, and the plates were incubated for 7–10 days at 25° C. As a general rule two plates were poured for each sample, and six samples were taken from each sooty mould investigated in this way.

Below are given the results of investigations of three typical sooty moulds collected in the Sydney district.

1. *Host, Eugenia* sp., attacked by *Ceroplastes rubens.*—The mould was fairly thin and newly formed. It was collected on 19th September, 1932.

Species of Fungus.	Number of Plates in which it occurred.	Number of colonies.	Percentage of total number of colonies.
Dematium pullulans	12	865	57·6
Cladosporium herbarum ...	10	552	36·7
Yeast	9	79	5·2
Penicillium sp.	5	5	0·3
Epicoccum sp.	1	1	0·06

2. *Host, Pittosporum undulatum,* attacked by *Ceroplastes ceriferus.*—The mould was thick and well established. *Capnodium salicinum* was present, and was fruiting prolifically. It was collected on 20th August, 1932.

Species of Fungus.	Number of Plates in which it occurred.	Number of colonies.	Percentage of total number of colonies.
Dematium pullulans	12	820	51·2
Cladosporium herbarum	12	394	24·6
Capnodium salicinum	9	282	17·6
Penicillium sp.	6	36	2·2
Yeast	5	25	1·5
Alternaria sp.	10	24	1·5
Asbolisia sp.	2	2	0·12
Epicoccum sp.	5	12	0·75
Others	4	4	0·25

3. *Host, Arbutus unedo,* attacked by *Ceroplastes rubens.—Antennularia scoriadea* was present. The mould was collected on 1st June, 1932.

Species of Fungus.	Number of Plates in which it occurred.	Number of colonies.	Percentage of total number of colonies.
Cladosporium herbarum	12	325	55·8
Dematium pullulans	12	108	18·5
Antennularia scoriadea	9	48	8·2
Yeast	10	42	7·2
Asbolisia sp. A	7	26	4·4
Alternaria sp.	5	14	2·2
Asbolisia sp. B	2	5	0·86
Penicillium sp.	2	3	0·5
Epicoccum sp.	2	3	0·5
Others	6	8	1·3

About 100 such investigations were carried out. It was found that some of the fungi, e.g., *Penicillium* spp., were only found occasionally, and in relatively small numbers. They therefore could not be regarded as permanent constituents of the sooty moulds. Others which occurred still less frequently, and were found perhaps only once in the course of an investigation, e.g., *Fusarium* sp., were considered to be purely accidental.

The percentages of the members of the Capnodiaceae shown by this method are often far short of the percentage expected from a microscopical investigation of the sooty mould. This is probably due to the fact that they grow very slowly in culture, and are frequently covered by the faster growing members of the Fungi Imperfecti.

The fungi found to be the commonest and most widespread are: *Dematium pullulans*, *Cladosporium herbarum*, *Asbolisia* spp., *Alternaria* spp., and *Triposporium* sp.

Dematium pullulans.—This fungus is present in greater or less degree in all the moulds so far investigated, and in some cases seems to form practically pure colonies. The mycelium is dark and more or less torulose. The conidia are difficult to identify microscopically as they resemble the resting spores of dark coloured yeasts. A number of different strains have been obtained, varying chiefly in the colour of the mycelium when grown on a standard agar.

Cladosporium herbarum.—This fungus is often found in association with *Dematium*, but under certain circumstances it may also form practically pure colonies. It is present in a great percentage of the New South Wales sooty moulds. Several strains, differing in the habit of growth on a standard agar, have been obtained.

Asbolisia spp.—These fungi are less common than *Cladosporium* and *Dematium*. They are characterized by having small round dark pycnidia and small hyaline spores.

Alternaria spp.—These fungi are widespread but never very abundant in sooty moulds. Those most frequently found are characterized by having a very dark coloured mycelium.

Triposporium sp.—This fungus is often present in sooty moulds. It is not so common as *Alternaria* but is widespread, and when present is very abundant and fruits profusely. It is easily identified by its large star-shaped conidia.

Other species of Fungi Imperfecti which can only be detected in culture and are much less frequent are: *Brachysporium* sp., *Penicillium* spp., *Epicoccum* spp., *Fusarium* spp., and yeasts, including pink, white and black coloured forms.

B. *Development and Distribution.*

It has been found in the course of the work that there are two types of sooty moulds present in the Sydney district, (i) perennial, and (ii) annual.

(i) Perennial Moulds.

The perennial type is by far the most common, and represents the highest development attained by the sooty mould community. A member of the Capnodiaceae is always dominant. These moulds re-establish themselves very rapidly if partly washed away by heavy rain or after flaking off the host leaves in dry weather. They are found exclusively on perennial plants.

(ii) Annual Moulds.

The annual type of mould is found on herbs which have been attacked by aphis. These moulds are commonest in damp weather, and consist exclusively of members of the Fungi Imperfecti, the dominant fungus being usually *Dematium* or *Cladosporium*.

The development of the sooty mould has been followed in a number of cases by selecting leaves showing various stages in the appearance of the mould from the earliest traces of mycelium to the final stage. Plate cultures have been

made from these leaves. Specimens of perennial and annual moulds have been examined in this way.

The first steps in the development are quite similar in each case. The nature of the pioneer fungus varies, but *Dematium* is by far the commonest. Occasionally the pioneer fungus may be a *Capnodium*, but usually this is only the case if the mould is developing on a shrub close to others which support a sooty mould in which a *Capnodium* is dominant. The growth of these first fungi forms a light network over the surface of the leaf, and this forms a matrix which catches and holds other fungal spores, and forms a ground mass in which they may germinate. *Cladosporium* usually appears quite early in the development of the mould.

The subsequent development depends largely on the environmental conditions. If the neighbouring moulds are of the annual type, or if there are no moulds in the vicinity, the new sooty mould will be composed of Fungi Imperfecti for a considerable period. In most cases, if the mould is on a perennial plant, development continues, so that after a longer or shorter period the final stage is attained This is effected by the appearance of a *Capnodium* which ultimately becomes the most important fungus in the mould. Other Capnodiums may also appear, and the mould takes on its perennial form. The time necessary for such a change depends on the chances of infection with a *Capnodium*.

In a few of the cases examined this development was not completed. Here fairly thick moulds had been formed by the growth of *Dematium pullulans*, with *Cladosporium* and yeast also present in small amounts. The mould was perennial and similar in outward appearance to those in which *Antennularia scoriadea* was dominant, but the luxuriance of the growth of the Fungi Imperfecti made it impossible for members of the Capnodiaceae to become established. Strong growth of *Dematium* appears, therefore, to be inimical to the growth of *Capnodium*.

In the case of annual plants the sooty mould formed may become fairly thick, but in all the cases examined it was composed of the annual type of fungus association. The annual mould may be taken as a stage in the development of a perennial mould, in which there is not sufficient time for a *Capnodium* to become established.

In the case of sooty moulds developing on a perennial plant in the vicinity of moulds in which a *Capnodium* is present, it has been found that development proceeds immediately to the formation of a mould of the perennial type without any intervening stage.

The members of the Capnodiaceae grow well together and seem to have no mutually antagonizing effect. On the other hand, as has been shown, a growth of *Dematium*, *Cladosporium* and yeasts forms a combination into which it is difficult for a *Capnodium* to enter. It has been found also that a strong development of *Alternaria*, *Asbolisia* and *Penicillium* considerably reduces the amount of *Dematium* and, to a less extent, *Cladosporium* present.

The fungi obtained from culture from the moulds can be classified into three groups:

1. *The Perennials.*—These are the chief constituents of the perennial moulds. They are characterized by having a dark, resistant mycelium which can withstand a considerable amount of desiccation, and can commence growth whenever conditions are favourable. The fungi included in this class are the members of the Capnodiaceae, *Atichia glomerulosa*, *Dematium pullulans*, *Cladosporium herbarum* and possibly *Triposporium*.

2. *The Ephemerals.*—These are the fungi other than *Dematium* and *Cladosporium* which make up the bulk of the annual moulds, and appear only in favourable weather. They decrease very considerably in amount during hot and dry weather, and reappear when climatic conditions are suitable. They evidently cannot withstand insolation to the same extent as do the members of the first class, and rely chiefly on their spores for tiding over adverse periods. This class is represented by *Alternaria*, *Brachysporium*, *Asbolisia*, *Epicoccum*, yeasts and possibly *Penicillium*.

3. *The Accidentals.*—These are fungi which develop from spores blown by chance on to the mould, and which grow only in the most favourable weather, dying off completely in hot dry periods. They never form an important part of the mould. They include *Fusarium* spp., *Mucor*, *Aspergillus*, bacteria, etc.

The Problem of Polymorphism.

A. *Historical Review.*

As pointed out in a previous section, the fact that a number of fungi may grow intermingled and fruit concurrently in a sooty mould, leads at once to the idea that there is a single polymorphic fungus concerned in its formation.

Tulasne assigned many imperfect forms to *Capnodium salicinum*, most of which were probably members of the Fungi Imperfecti.

Thuemen (1890) also spoke of the extraordinary diversity of the spore forms of the "Russtaupilze". Penzig included as an imperfect stage of *Meliola camelliae* the colonies of *Atichia* associated with it. The work of Zopf on a rather polymorphic species gave such ideas much support. Laurent went to the extreme of trying to correlate a number of distinct species of the Fungi Imperfecti culturally, suggesting that they were identical, and the imperfect stages of *Capnodium salicinum*.

Schostakowitsch (1895), Berlese (1895), and Planchon (1902) did much to establish the fact that the more common conidial forms associated with sooty moulds are separate fungi.

When McAlpine described *Capnodium citricolum* (1896*a*), he made a special study of the spore forms associated with it. That he was alive to the possibility of other fungi being involved in the production of the mould is clear, since he said (p. 470): "In order to prove the fact of polymorphism it would be necessary to sow pure cultures and watch the development of the different forms under strictly test conditions, for otherwise the forms found together might be really different, and constitute merely a case of association." He described seven imperfect forms for *C. citricolum* and five for *C. callitris* (1896*b*).

Von Hoehnel (1909*b*) also spoke of the diversity of the conidia produced by members of the Capnodiaceae, which, he said, include *Torula*, *Triposporium*, *Helminthosporium*, etc., together with many kinds of pycnidia which are often vertically elongate.

Vuillemin (1908) pointed out that Bernard had described and figured *Seuratia* (i.e., *Atichia*) in the life histories of *Capnodium javanicum* Zimm. and *C. stellatum* Bern. from Java.

Arnaud (1910*b*) also considered that *Atichia* was a stage in the development of the Capnodiaceae.

The more recent workers on the sooty moulds are inclined to limit the number of spore forms attributable to the members of the Capnodiaceae. Both Woronichin (1926) and Boedijn (1931) spoke of *Triposporium* and other spore

forms as being associated with these fungi, but considered that they were probably distinct from them. Boedijn has, however, reported that he has observed yeast-like budding of the mycelium of *Chaetothyrium* and *Capnodium*.

Gaumann (1928) spoke of the great diversity of the conidial fructifications of the Capnodiaceae.

Similarly, imperfect conidial and pycnidial forms have been attributed to the species of the parasitic genus *Meliola* and related fungi, but it has been shown by Stevens (1918) that these are separate fungi associated with *Meliola* and are in most cases probably parasitic upon it.

In the same way it is probable that in all cases the spores of genera of the Fungi Imperfecti which have been found associated with the Capnodiaceae are produced by associated fungi, and that the only imperfect fruits produced by the Capnodiaceae are pycnidia, and that these are always specific.

B. *Cultural Evidence.*

The strongest evidence that a variety of pycnidial forms may be attributed to the one sooty mould fungus is provided by the researches of Zopf. It must be pointed out, however, that the fruits described by him, except for a few yeast-like forms which were probably contaminants, all produced spores of the same size and shape. Moreover, all the types of fructifications were related by a large number of intermediate fruit bodies, and could be placed in a definite series. The various pycnidial fruits which were described, for instance, for *Capnodium citricolum* by McAlpine bear no such relation to one another, and produce spores of greatly varying size and shape.

The fructifications described by McAlpine for *Capnodium citricolum* are reviewed below:

1. *Coniothecium.*—A fungus which produces spores similar to this has been isolated by Neger (1918) and is quite distinct from *Capnodium*. This fungus, however, has not yet been isolated from New South Wales sooty moulds and may not occur here. On the other hand, the *Coniothecium*-like gemmae described by McAlpine are quite common. In some cases these gemmae constitute practically the whole of a light mould. To determine the nature of these fungi, cultures have been made, and in every case *Dematium pullulans* or a black yeast is obtained. These two fungi form very similar gemmae.

2. *Glomerulae.*—As has been previously pointed out, these are probably colonies of an associated fungus, *Atichia*.

3. *Triposporium.*—Spores similar to those described have been found many times. Cultures of these spores have been made from a diverse number of sooty moulds, and in all cases gave rise to pure cultures of an imperfect fungus bearing *Triposporium* spores alone.

4. *Spermogonia.*—These are short pycnidia with small rod-like spores.

5. *Antennaria.*—These are pear-shaped or oval pycnidia with small round or oval spores.

6. *Ceratiopycnidia.*—These are elongated or cylindrical pycnidia producing oval, single-celled, hyaline spores.

7. *Pycnidia.*—These are also elongated and cylindrical, and produce spores which are one to three septate, and hyaline or brown.

Pycnidia of all these types have been found and cultures made from the spores produced by them. In each case the fungus obtained from one type of pycnidium differed essentially from the fungi obtained from the pycnidia of other

kinds, and it is certain that a number of different fungi are involved in the production of the diverse types described as belonging to the one fungus by McAlpine.

Spore cultures from the "pycnidia" yield cultures which are identical with ascospore cultures of *Capnodium salicinum*. It is, therefore, certain that these fructifications do not form part of the life cycle of *C. citricolum*.

The small "*Antennaria*" pycnidia are referable to *Antennularia scoriadea*.

Two types of pycnidium, therefore, remain unaccounted for, the Spermagonia, and the Ceratiopycnidia. Of these, it is probable that one is really the imperfect form of *C. citricolum*, but until ascospore cultures can be made, it is impossible to decide which.

To test the hypothesis of polymorphism further, spores of *Alternaria* and *Cladosporium* were cultured directly from a diverse number of moulds. In all cases pure cultures of *Alternaria* and *Cladosporium* were obtained. No other fruit bodies were produced by these fungi in culture.

To date no evidence has been obtained culturally that any of the Capnodiaceae produce conidia of any kind, or pycnidia of more than one kind.

Conclusions.

The results given above indicate that the New South Wales sooty moulds show resemblances, on the one hand, to sooty moulds of tropical regions, in that several species are commonly found contributing to the formation of a single mould. On the other hand, there are resemblances to the sooty moulds of the cool north temperate regions. Such saprophytes as *Cladosporium herbarum*, *Dematium pullulans* and *Atichia glomerulosa* are common and widespread in New South Wales, as well as in the north temperate region. The absence from the New South Wales sooty moulds of *Botrytis cinerea*, bacteria, and many fungi recorded by Neger is noteworthy. In this respect the local moulds seem to be intermediate in type between those of the tropical and those of the temperate regions.

The habitat of the mould is a peculiar one, and the fungi which thrive in it must possess modifications or properties which enable them to exist under conditions which show a great range of temperature, light intensity and humidity. They must be able to utilize casual moisture such as rain and dew, as well as honey-dew, for growth, and remain unhurt through periods of great insolation.

In the temperate parts of the earth sooty moulds are best developed in moist cool weather, when the light intensity is less than maximum. These conditions are favourable for the growth of fungi generally, and it is therefore not remarkable that the sooty mould should include the common saprophytes of decay.

On the other hand, tropical sooty moulds live under atmospheric conditions differing from those obtaining in temperate countries. Temperature, light intensity and humidity all have a high value, and the result is that there is a great variety of specialized fungi present, chiefly members of the Capnodiaceae, which are restricted entirely to the honey-dew covered parts of plants for their development.

Scale Insects Concerned.

The following important scale insects associated with the formation of sooty moulds in New South Wales have been kindly determined by Mr. Froggatt.

Ceroplastes ceriferus on *Pittosporum*, *Bursaria*, *Laurus*, *Citrus* spp., and many other plants.

Ceroplastes rubens, particularly on *Eugenia* spp., but also very common on *Bursaria*, *Citrus* and many other plants.

Lecanium hesperidum, on *Bursaria*, *Citrus*, *Castanospermum*, etc.

Tachardia melaleucae, on *Leptospermum* spp.

Others with which sooty moulds have been found associated are: *Eriococcus eucalypti*, on *Bursaria spinosa*; *Ctenochiton eucalypti*, on *Angophora* spp.; *Dactylopius albizzia*, on *Acacia discolor*; *Eriococcus leptospermi*, on *Leptospermum* spp.; and *Mytilaspis crassi*, on *Jacksonia* sp.

The identity of the scale insects associated with the mould appears to exert little influence on the species of fungi which occur. Similar moulds may develop on the secretion of different species of scale insects as far as conditions of environment permit.

Summary.

1. A brief historical account is given of work done on the composition, systematics and physiology of sooty mould fungi. Sooty moulds usually consist of a number of different fungi growing together to form a community. These fungi belong to the following groups: (*a*) *Capnodiaceae*, which includes the most conspicuous and important members of the flora; (*b*) *Atichiaceae*, the commonest species of which, *Atichia glomerulosa*, is a widespread constituent of sooty moulds; (*c*) *Fungi Imperfecti*, which may in some cases be present to the exclusion of all other kinds of fungi. Of these, *Dematium pullulans* and *Cladosporium herbarum* are the most important.

2. A review of the species of sooty moulds reported from New South Wales is given.

3. It has been found that in New South Wales the sooty moulds *Capnodium salicinum* and *Antennularia scoriadea* are the commonest members of the Capnodiaceae present. *Atichia glomerulosa* and the Fungi Imperfecti, *Dematium* and *Cladosporium*, are widespread.

4. There are two types of sooty moulds in New South Wales: (*a*) Perennial moulds which develop on perennial shrubs and trees; (*b*) annual moulds which develop on annual herbs attacked by aphis, and which often precede the perennial moulds on trees and shrubs. The perennial mould consists of members of the Capnodiaceae, together with *Atichia* and a variety of the Fungi Imperfecti. The annual mould consists largely of *Dematium*, *Cladosporium*, *Alternaria*, *Asbolisia*, *Triposporium*, yeasts, etc.

5. *Dematium* is the pioneer fungus of the sooty mould flora in most cases.

6. It is shown that all the spore forms attributed by McAlpine to *C. citricolum* do not belong to the one species.

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While this paper was in the course of preparation for the press the writer was fortunately able to see, through the kindness of Miss E. E. Fisher, M.Sc., of Melbourne, an advance proof of a paper by her: "On the 'Sooty Moulds' of some Australian Plants", which is to appear in *Proc. Roy. Soc. Victoria*, 45 (N.S.), Pt. 2, 1933. Miss Fisher considers that the fungi *Capnodium citricolum* McAlp., and *C. Walteri* Sacc., are identical with *C. salicinum* Mont. She follows the nomen-

clature of Arnaud and Gaumann, referring the fungus to the genus *Teichospora*. Miss Fisher's conclusions will be discussed at greater length in a later communication.

Literature Cited.

ARNAUD, G., 1910*a*.—Contribution à l'étude des Fumagines. *Ann. Myc.*, vii, pp. 470-476.

————, 1910*b*.—Contribution à l'étude des Fumagines. 1. *Limacinia, Seuratia, Pleosphaeria*, etc. *Ann. Ecole nationale Agric. Montpellier*, Sér. 2, Tome ix (4), pp. 239-277.

————, 1911.—Contribution à l'étude des Fumagines. 2. Systématique et Organisation des Espèces. *Ibid.*, Tome x (iii/iv), pp. 211-330.

————, 1912.—Contribution à l'étude des Fumagines. 3. *Ibid.*, Tome xii (i), pp. 1-34.

DE BARY, A., 1887.—Comparative Morphology and Biology of the Fungi, Mycetozoa and Bacteria. English Translation.

BENNETT, F. T., 1928*a*.—On *Cladosporium herbarum*: The Question of its Parasitism, and its Relation to "Thinning out" and "Deaf ear" in Wheat. *Ann. Appl. Biol.*, xv, pp. 191-212.

————, 1928*b*.—On *Dematium pullulans* de B. and its Ascigerous Stage. *Ann. Appl. Biol.*, xv (3), pp. 371-392.

BERLESE, A. N., 1895.—Première Contribution à l'étude de la Morphologie et de la Biologie de *Cladosporium* et *Dematium*. *Bull. Soc. Myc. Fr.*, xi, p. 72.

BOEDIJN, K. B., 1931.—Notes on Some Sooty Moulds. *Bull. Jardin Botan. Buitenzorg*, Ser. 3, xi (2), pp. 220-231.

CLEMENTS, F. E., 1909.—The genera of Fungi. Minneapolis, U.S.A

CLEMENTS, F. E., and SHEAR, C. L., 1931.—The Genera of Fungi. New York.

COOKE, M. C., 1892.—Handbook of Australian Fungi. London.

COTTON, A. D., 1914.—The Genus *Atichia*. *Kew Bull. Misc. Information*, pp. 54-63.

*FARLOW, W. G., 1876.—On a Disease of Olive and Orange Trees, occurring in California. *Bull. Bussey Instit.*, pp. 404-414.

*GAILLARD, A., 1892.—Le Genre *Meliola*. Paris.

GAUMANN, E. A., 1928.—Comparative Morphology of the Fungi. Translated by C. W. Dodge. New York.

HOGGAN, Ismé A., 1923.—On *Dematium pullulans* de Bary. *Trans. British Mycological Society*, vol. ix (i/ii), pp. 100-107.

VON HOEHNEL, F., 1909*a*.—Fragmente zur Mykologie (viii Mitt., nr. 354-406). Nr. 355. Was ist *Apiosporium* Kunze. *Sitz. K. Akad. Wiss., Math.-Nat. Kl.*, 118 (1), pp. 1159-1161.

————, 1909*b*.—Fragmente zur Mykologie (viii Mitt., nr. 354-406). Nr. 379. Über *Limacinula samoënsis* von H. *Ibid.*, pp. 1193-1201.

————, 1909*c*.—Fragmente zur Mykologie (ix Mitt., nr. 407-467). Nr. 431. Über *Antennaria scoriadea* Berk. *Ibid.*, p. 1461.

————, 1910*a*.—*Atichia Treubii* v. H. (Saccharomycetes). *Ann. Jardin Botan. Buitenzorg*, Supp. 3, pp. 19-28.

————, 1910*b*.—*Fragmente zur Mykologie* (xi Mitt., nr. 527-573). Nr. 532. Ubersicht der Capnodiaceen-gattungen. *Sitz. K. Akad. Wiss., Math.-Nat. Kl.*, 119 (1), p. 625.

————, 1918.—Fragmente zur Mykologie (xxi Mitt., nr. 1058-1091). Nr. 1089. Über die Capnodiaceen und Coccodinieen. *Ibid.*, 1927 (1), pp. 386-389.

LAURENT, G., 1897.—Recherches sur le Polymorphisme du *Cladosporium herbarum*. *Ann. Inst. Pasteur*, ii, pp. 558-566, 581-603.

LINDAU, G., 1897.—Perisporiales. Die Naturlichen Pflanzenfamilien, Engler und Prantl, Teil 1, Abt. 1.

MANGIN, L., et PATOUILLARD, N., 1912.—Les Atichiales, groupe aberrant d'Ascomycètes inférieurs. *C. R. Acad. Sci. Paris*, 154, pp. 1475-1481.

MCALPINE, D., 1895.—Systematic Arrangement of Australian Fungi. Melbourne.

————, 1896*a*.—The Sooty Moulds of Citrus Trees, a Study in Polymorphism. PROC. LINN. SOC. N.S.W., xxi, pp. 469-497.

————, 1896*b*.—Two Additions to the Fungi of New South Wales. PROC. LINN. SOC. N.S.W., xxi, p. 722.

MENDOZA, J. M., 1932.—Two New Species of Sooty Molds from the Philippines. *Philippine Journ. Sci.*, vol. 47 (2), pp. 289-294.

MONTAGNE, C., 1849.—De Capnodio, nov. gen. *Ann. Sci. Nat.*, Sér. 3, Tome 11.

NEGER, F. W., 1918.—Experimentelle Untersuchungen über Russtaupilze. *Flora*, N.F. 10, pp. 67-139.

PATOUILLARD, N., 1904.—Description de quelques champignons nouveaux des Iles Gambier. *Bull. Soc. Myc. Fr.*, xx, pp. 134-138.

————, 1906.—Champignons recueillis par M. Seurat dans la Polynésie française. *Bull. Soc. Myc. Fr.*, xxii, pp. 45-62.

PLANCHON, L., 1900.—Influence de Divers Milieux Chimiques sur Quelques Champignons du Groupe des Dematiées. *Ann. Sci. Nat.*, Sér. 8, Tome 11, pp. 1-248.

*PENZIG, O., 1882.—Studi botanici sugli agrumi e sulle piante affine. *Annali di Agricoltura Roma*, xxiv.

SAWHNEY, A., 1927.—Studies in the Biological and Cultural Characters of *Capnodium* sp. on Cotton. *Journ. Indian Botanical Society*, v (4), pp. 141-186.

*SCHOSTAKOWITSCH, W., 1895.—Über die Bedingungen der Conidienbildung bei Russthaupilzen. *Flora*, 81, p. 366.

SORAUER, P., 1908.—Handbuch der Pflanzenkrankheiten.

SPEGAZZINI, C., 1918.—Notas Mycologicas. *Physis*, iv (17), pp. 281-295.

STEVENS, F. L., 1918.—Some Meliolicolous Parasites and Commensals from Porto Rico. *Bot. Gaz.*, 65 (3), pp. 227-249.

————, 1925.—Hawaiian Fungi. *Bernice P. Bishop Museum Bull.*, 19, pp. 52-62.

THEISSEN, F., 1913.—Über einige Microthyriaceen. *Ann. Mycol.*, xi, pp. 493-511.

————, 1916.—Mykologische Abhandlungen i-iv. iii. Über *Saccardinula* Speg. und die Naetrocymbeen. *Verh. Zool. Bot. Gesellsch. Wien*, 66, pp. 350-365.

THEISSEN, F., und SYDOW, H., 1917.—Synoptische Tafeln. Hemisphaeriales, Myriangiales, Perisporiales, Trichothyriaceae. *Ann. Mycol.*, 15, pp. 389-491.

*VON THUEMEN, F., 1890.—Russthau und Schwärze. Neue Beobachtungen und zusammenfassende Mitteilungen über die unter dem Namen "Russthau", "Schwarze" u.s.w. bekannten Krankheiten unserer Kulturgewächse. Aus den Laboratorien der k.k. Chemisch- Physiolog. Versuchsstation fur Wein- und Obstbau zu Klosterneuburg b. Wein. No. 13, 1 (Review in *Cent. f. Bact. und Parasitenk.*, viii).

TULASNE, L. R., et C., 1863.—Selecta Fungorum Carpologia, vol. 2, p. 264. Trans. by W. B. Grove, edit. by A. H. R. Buller and C. L. Shear. Oxford, 1931.

VUILLEMIN, P., 1905.—*Seuratia pinicola*, sp. nov. Type d'une nouvelle famille d'Ascomycètes. *Bull. Soc. Myc. Fr.*, xxi, pp. 74-80.

————, 1908.—Le genre *Seuratia* et ses connexions avec les *Capnodium*. *C. R. Acad. Sci. Paris*, cxxxxv, pp. 307-308.

WEBBER, H. J., 1897.—Sooty Mold of the Orange and its Treatment. *U.S. Dept. Agr., Divn. of Veg. Physiol. and Path.*, Bull. 13, pp. 1-34.

WORONICHIN, N. N., 1925.—Über die Capnodiales. *Ann. Mycol.*, 23, pp. 174-178.

————, 1926.—Zur Kenntnis der Morphologie und Systematik der Russtaupilze Transkaukasiens. *Ann. Mycol.*, 24, pp. 231-265.

ZOPF, W., 1878.—Die Conidienfrüchte von *Fumago*. *Nova Acta K. Leop.-Carol.-Deutschen Akad. Naturf.*, xl, Nr. 7, pp. 257-329.

Abstracts only of papers marked thus * were available to the writer.